Collision Resolution for Emergency Traffic in Body Area Networks

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Abstract

Application of sensor networks in health care has created a new field called the body area networks (BAN). It has been gaining wider acceptance lately. Traffic in a BAN can be divided into two categories – normal traffic, which can be scheduled by a doctor or the patient and emergency traffic, which are random. Handling emergency traffic is a very sensitive and tricky issue in a BAN. In this paper, we propose a scheme to transmit emergency traffic using an out-of-band wakeup system. The performance analysis is presented for energy consumption and lifetime.

1. Introduction

Development of wireless networks to monitor human body functions has given rise to a new field called wireless body area networks [1]. A typical BAN structure is shown in Fig 1. It consists of nodes (BN) and a coordinator (BNC). A BAN can have normal (scheduled) and emergency traffic (random). Low energy consumption, delay, lifetime and security are among the key design factors for a BAN.

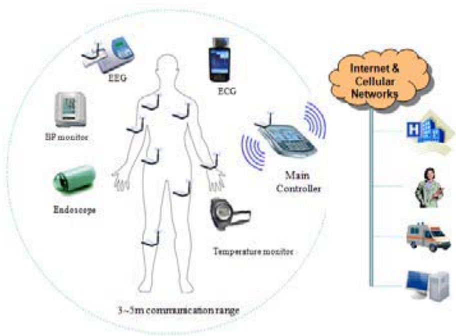

Fig 1. Structure of a BAN.

Authors [1-4] have proposed out-of-band wakeup radio system for sensor networks. The wakeup radio mechanism works on the basic idea that a node can be woken up by external trigger. It can be effectively used in an unscheduled environment.

In this paper, we propose a mechanism for emergency communication using wakeup radio. A node with emergency data can use wakeup radio to wakeup the sink node. Our aim is to reduce energy consumption and thereby increase lifetime of the nodes. The rest of the paper is organized as follows. In Section 2, we present system design. In Section 3, we present performance analysis. In Section 4, we present results and discussion. Finally, conclusions are drawn in Section 5.

2. System Design

The proposed system employs two channels of communication – one for wakeup radio and other for data. When a BN senses emergency, it wakes up and attempts to send emergency packet to the sink node. The data communication model between a BN and BNC in a non-beacon enable network is shown in Fig 2. In this case, a BN wakes up and sends a wakeup radio packet to the BNC. BNC acknowledges it by sending a wakeup acknowledgement (WACK) packet. It is followed by data, which is optional. In the case of more than one BNs having emergency at the same time, collision occurs.

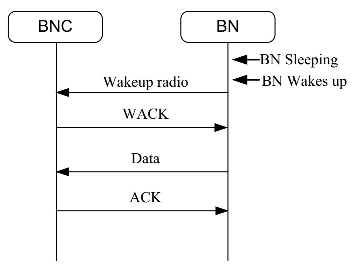

Fig 2. Emergency communication.

3. Analysis

We have used a slotted contention based mechanism. A BN with an emergency event uses channel sensing to check the channel for activity. If it senses an idle channel, it transmits the emergency wakeup radio packet. In case of a busy channel, it uses random back-off before commencing a transmission. Each BN selects a back-off value from the range [0, B]. The average back-off size is given by,

$$\overline{B} = \frac{B-1}{2} \quad (1)$$

We assume that the emergency traffic follows Poisson distribution with arrival rate λ. Let α be the attempt rate of the wakeup radio. For a network with N nodes, the total rate is given by Nα. Let T_s be the duration of a slot.

For analysis, we consider the two periods- idle and active. The idle period is the time when a BN does not transmit or receive. In the idle period, a BN can shut down the transceivers and go to sleep state. Thus, a BN is said to be idle from the end of the last packet transmission till the start of the next transmission. Similarly, a BN is active from the moment a transmission starts till end of the transmission.

The cumulative distribution of the duration from the end of the last packet transmission till the start of the arrival of the next packet (T_x) is given by,

$$P\left(T_x \le x\right) = 1 - P\left(T_x > x\right) = 1 - e^{-N\alpha x} \quad (2)$$

The mean of this is also equal to the mean duration of the idle period and given by,

$$E\left[T_i\right] = E\left[T_x\right] = \frac{1}{N\alpha} \quad (3)$$

The active period is given by,

$$T_a = T_{wk} + A \quad (4)$$

where T_{wk} is the duration of the wakeup radio. It is the summation of the time required to send wakeup radio packet and receive wakeup acknowledgement. It is given by,

$$T_{wk} = T_{wbn} + T_{wack} \quad (5)$$

The parameter A is a random variable with mean,

$$E\left[A\right] = T_s - \frac{1-e^{-(N-1)\alpha T_s}}{(N-1)\alpha} \quad (6)$$

We calculate the energy consumption considering the successful transmission during an emergency event. During the active period, let p_b be the busy channel probability. The corresponding idle channel probability is given by (1- p_b). During an active period, the transmission follows Poisson process with rate of α(1- p_b). In an active period at the BN, it spends some time in idle period. The mean idle period within the active period is given by,

$$E\left[T_{ai}\right] = \frac{1}{(1-p_b)\alpha} \quad (7)$$

The mean busy period at the transmitter is equal to the time of transmitting the wakeup emergency command packet. It is given by,

$$E\left[T_{at}\right] = T_{wbn} \quad (8)$$

The proportion of time a BN spends in transmitting is given by,

$$T_{tx} = \frac{E\left[T_{at}\right]}{E\left[T_{ai}\right] + E\left[T_{at}\right] + E\left[T_{ar}\right]} \quad (9)$$

The proportion of time a BN spends in receiving is given by,

$$T_{rx} = \frac{E\left[T_{ar}\right]}{E\left[T_{ai}\right] + E\left[T_{at}\right] + E\left[T_{ar}\right]} \quad (10)$$

The mean busy period at the receiver is equal to the time of receiving the wakeup acknowledgement packet. It is given by,

$$E\left[T_{ar}\right] = T_{wack} \quad (11)$$

The final expression for T_{tx} and Trx are as follows,

$$T_{tx} = \frac{(1-p_b)\alpha T_{wbn}}{1+(1-p_b)\alpha T_{wbn} + (1-p_b)\alpha T_{wack}} \quad (12)$$

$$T_{rx} = \frac{(1-p_b)\alpha T_{wack}}{1+(1-p_b)\alpha T_{wbn} + (1-p_b)\alpha T_{wack}} \quad (13)$$

The proportion of time a BN spends in idle is given by,

$$T_{id} = \frac{E\left[T_a\right]}{E\left[T_i\right] + E\left[T_a\right]} - T_{tx} - T_{rx} \quad (14)$$

Let E_{em} be the energy consumption during emergency communication. It is calculated by adding energy consumption in transmitting, receiving, idle and other overheads. It is given by,

$$E_{em} = T_{tx}P_{tx} + T_{rx}P_{rx} + T_{id}P_{id} + E_{ov} \quad (15)$$

E_{ov} is the overhead energy consumption. It is given by,

$$E_{ov} = P_{tr}T_{tr} + P_{sw}T_{sw} \quad (16)$$

Lifetime (in number of days) is calculated as follows,

$$Lifetime = \frac{Initial\ Battery\ Energy}{E_{em} \times 365 \times 24} \quad (17)$$

5. Results and Discussion

We have simulated our work using Network Simulator NS-2 (release v2.31). The input parameters presented in Table 1 are taken from [5-6].

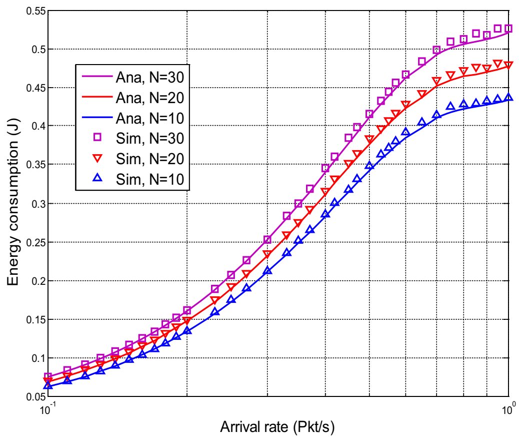

Fig 3. Energy consumption.

The total energy consumption is shown in Fig 3. The energy consumption is reasonably low. The proposed system does not require beacon which means reduced overheads. It also does not require the receiver to remain awake for intended transmission thereby reduced idle listening which is common in most of the present systems. The wakeup radio scheme helps to reduce overheads energy consumption. A separate channel based wakeup radio and backup mechanism is able to minimize collision.

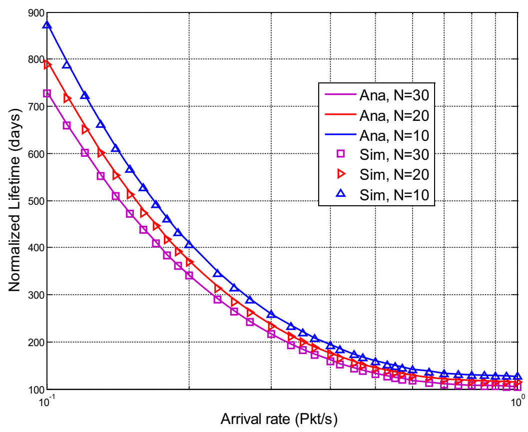

Fig 4. Lifetime.

The lifetime is shown in Fig 4. Due to use of wakeup radio, a node can stay in sleep state until awoken by a wakeup signal from other node. The proposed scheme also avoids control packet overheads. It is able to achieve higher lifetime by reducing these overheads and lowering energy consumption.

Table 1. Input Parameters.

Terms	Values	Terms	Values	Terms	Values
P_{tx}	27mW	T_{tr}	0.8ms	P_{id}	0.0035mW
P_{rx}	1.8mW	T_{sw}	0.4ms	B	32
P_{sw}	14.39mW	T_{wbn}	2.56ms	R	25kbps
P_{tr}	0.004mW	T_{wack}	3.2ms	λ	variable

6. Conclusions

Body area network is one of the major growth areas. In this paper, we propose a scheme to communicate in a BAN using wakeup radio. A wakeup radio based system can reduce overheads and thereby a significant amount of energy can be saved It helps to increase the lifetime of the nodes. It also minimized the need of unnecessary wakeup time for the nodes. Our next work involves comparing the proposed method with existing protocols.

Acknowledgement

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